PHOSPHORESCENT FUNGI IN AUSTRALIA.

By D. McAlpine.

(Communicated by J. H. Maiden, F.L.S.)

(Plates xxxi.-xxxii.)

The phenomenon of phosphorescence or luminosity in fungi has long been known, but the cause of it is still in dispute. Plenty of specimens displaying it were met with in the suburbs of Melbourne during May, and by calling attention to the fact someone with the time and opportunity may be induced to investigate the phenomenon. My principal reason, however, for dealing with the subject now is to bring forward some fresh material which, if it does not throw any new light upon the matter, may at least remove some sources of error.

The following account of the phenomenon is given by Dr. Cooke in his "Introduction to the Study of Fungi":—"Several Agarics have this property, of which the largest number, for any locality, have been met with in Australia. All of them are species found growing upon dead wood and all have white spores. Nearly the same story is related of all of them—to the effect that they emit a light sufficiently powerful to enable the time on a watch to be seen by it. 'The effect produced by it upon the traveller, when on a dark night he comes suddenly upon it glowing in the woods is startling; for to a person unacquainted with this phenomenon the pale, livid and deadly light emanating from it conveys to him an impression of something supernatural, and often causes no little degree of terror in weak minds or in those willing to believe in supernatural agencies' [Bennett]. The kind of light emitted in all cases is described as shining with a pale, livid and greenish phosphorescent glow." And the late Dr. Bennett in his "Gather-

ings of a Naturalist," says :—"There is a species of the genus *Agaricus* which has been observed to be vividly luminous. It is very common in the Australian woods in the vicinity of Sydney about the localities of the South Head Road and among the scrubs and forests on the approach to the headlands of Botany Bay, and emits a light sufficiently powerful to enable the time on a watch to be seen by it.

"I have frequently gathered this fungus, and on placing it in a dark room found that it has retained the luminous power for two successive nights; the phosphorescence becoming fainter on the second, disappears entirely by the third night. The whole of the plant shines with a pale, livid and greenish phosphorescent glow."

The naturalist Drummond has likewise vividly described the phenomenon in "Hooker's Journal of Botany" for 1842 and 1843, in letters written from Swan River, West Australia. He says:—"Two species of *Agaricus* grow parasitic on the stumps of trees and possess nothing remarkable in appearance by day, but by night they emit a most curious light, such as I never saw described in any book. The first species in which I observed this property was about two inches across and growing in clusters on the stump of a *Banksia* tree near the jetty at Perth, W.A. When this fungus was laid on a newspaper, it emitted by night a phosphorescent light, enabling us to read the words round it, and it continued to do so for several nights with gradually decreasing intensity as the plant dried up." The other species was remarkably large, measuring 16 inches in diameter, and weighing about five pounds. The specimen was hung up to dry in the sitting-room, and in passing through the apartment in the dark it was found to glow. "No light," he says, "is so white as this, at least none that I have ever seen. The luminous property continued, though gradually diminishing, for four or five nights, when it ceased on the plant becoming dry. We called some of the natives and showed them this fungus when emitting light, and the poor creatures cried out 'chinga,' their name for a spirit, and seemed much afraid of it."

On another occasion he saw at a distance a tree in the forest aglow, and he imagined that it must have been set in a blaze by lightning. "On making my way to it, I found that the light was produced by a remarkable Agaric which grew, tier above tier, up the trunk of a dead *Eucalyptus occidentalis*." The species was different from those previously described.

The descriptions of the phenomenon here given by two good observers on the spot will serve as a general introduction to the subject.

Fungi possessing this property.

The number of phosphorescent species is not large, only about 21 being determined with certainty, and they are generally natives of warm climates and belong mostly to the family *Agaricaceæ*. Of these no less than five are confined to Australia, and fifteen of them altogether are known in our island continent. Only some of those detected by Drummond have been determined, and a number probably await investigation.

The following list gives the known species, chiefly according to Zopf,* and I have added the distribution of those found in Australia. This will enable collectors to seek for those at present unknown or undescribed.

1. *Armillaria mellea*, Vahl. Europe, America, and Australia; very common.
2. *Pleurotus candescens*, F.v.M. Victoria; New South Wales (Baker*); on dead wood.
3. *P. facifer*, B. & C. United States.
4. *P. gardneri*, Berk. Queensland, on half rotten fronds of Palm; Brazil.
5. *P. igneus*, Rumph. Amboyna.
6. *P. illuminans*, F.v.M. New South Wales, Victoria, Queensland; on dead wood.

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* Die Pilze, p. 195 (1890).

* Proc. Linn. Soc. N.S. Wales, 1899, p. 446.

7. *P. lampas*, Berk. Victoria, West Australia, Tasmania; on languid but not dead stems of *Grevillea*.
8. *P. nidiformis*, Berk. West Australia; on the ground.
9. *P. noctilucens*, Lev. Manilla; on tree stems.
10. *P. olearius*, Dec. S. and S.E. Europe; among roots of Olive trees.
11. *P. phosphoreus*, Berk. Tasmania; on roots of trees.
12. *P. prometheus*, B. & C. Hong Kong; on dead wood.
13. *Collybia cirrhata*, Pers. Germany, Britain.
14. *C. longipes*, Bull. Germany, Britain, Victoria, Queensland.
15. *C. tuberosa*, Bull. Germany, Britain, Queensland.
16. *Fomes annosus*, Fr. Europe, America, Queensland.
17. *Polyporus grammocephalus*, var. *emerici*. Queensland, on trunks; New Guinea.
18. *P. sulphureus*, Fr. Europe, Asia, Africa, America, Queensland, Tasmania.
19. *Corticium coeruleum*, Fr. New South Wales, Queensland, Britain; said to be phosphorescent.
20. *Xylaria hypoxylon*, Grev. Europe, Australia; common.
21. *X. polymorpha*, Grev. Europe, Australia; common.

In the Honey Agaric (*A. mellea*) and the species of *Xylaria* it is only the mycelial threads which are phosphorescent, and the brilliant luminous appearance often seen in mines is due to the so-called rhizomorphs of the same or similar fungi. It is curious to note that the fructification which arises from these mycelial threads and is the perfectly developed form should not exhibit luminosity.

Tulasne,* writing in 1848, remarks that four species only of luminous Agarics appear at present to be known, viz., *Pleurotus gardneri*, *P. igneus*, *P. olearius*, and *P. noctilucens*, Lev., whereas at least twenty-one are now known and probably several are unrecorded for Australia.

* "Sur la Phosphorescence des Champignons." Ann. Sci. Nat. ix. p. 338 (1848).

In the original descriptions of the Australian species notes are often given as to the nature of the luminosity, since this could only be observed in the fresh state. A few of these remarks are here reproduced.

Pleurotus candescens—"Its luminosity is of a silvery shine and very apparent; it is partially restored to it when moistened again" (Mueller).

Pleurotus gardneri—"The whole plant gives out at night a bright phosphorescent light, somewhat similar to that emitted by the larger fire-flies, having a pale greenish hue. From this circumstance and from growing on a palm, it is called by the inhabitants 'Flor de Coco'" (Gardner).

Pleurotus illuminans—"We have now before us a luminous mushroom, by which in a dark room last night we were able to read distinctly the headlines of several newspapers" (Collector to Mueller).

Pleurotus phosphoreus—This species was so phosphorescent that Mr. Gunn, who discovered it in Tasmania, was able to read by its light, and it remained luminous six days or more.

While the observations regarding the nature of the light and the general effect produced are valuable, still there are various points requiring minute inspection on which even good observers were in error. Thus De Candolle, who first made known the remarkable phosphorescence of *P. olearius*, or the Olive-tree Agaric, made the mistake of stating that the property was only manifested at the time of decomposition, whereas it ceases when death occurs. Fries, too, in describing the mould *Cladosporium umbrinum*, found upon the same Agaric, considered that the luminous property was due to its presence, but on other luminous Agarics there are no such moulds, and the opinion is without foundation. Then again the entire fungus is often said in a general way to be luminous, but close inspection is required to settle what parts really glow.

There is another general statement often made that is open to question, that luminous fungi are only found on dead wood.

They certainly occur on the trunks of living trees, although the bark of the particular portion to which they are attached is dead, but that is probably due to the destructive action of the mycelium of the fungus.

Observations on Pleurotus candescens, F.v.M. & Berk.

Specimens of this fungus are very common during April and May in the neighbourhood of Melbourne, and a few observations were made on the phenomenon of phosphorescence this year.

Specimens were detached from a Tea-tree trunk on the afternoon of 6th April and retained their phosphorescence for at least a week.

The luminosity was confined to the gills, with the exception of the downy material (mycelium) at the base of the stem, from which, however, it disappeared in about two days. Portions of the cuticle were removed from the pileus, also the white flesh, but there was not the slightest trace of phosphorescence. The white spores were shed in great abundance, but they showed no signs of luminosity.

The phenomenon was exhibited during the day as well as at night, for when specimens were taken into a dark cellar they shone equally well.

The effect of moisture was also tested by immersing a piece of the gills in water. After immersion for an hour and a half, no perceptible effect on the luminosity was observed except, perhaps, it was just a shade duller.

The light emitted was a whitish glimmer with a faint suggestion of blue, but the phosphorescent light is not the same in all species of fungi. In some species it is more bluish, in others more greenish or greenish-yellow, and in a third more of the white light. The gills gave a decided acid reaction when fresh and in the full glow of luminosity.

In order to test the effect of the luminous glow on the photographic plate, Mr. A. J. Campbell, F.L.S., kindly tried a specimen. He exposed an ordinary photographic plate for an hour above

one of the luminous fungi, measuring about 4 or 5 inches in diameter. The result was that the plate was distinctly "fogged" from the action of the light and was not so affected when exposed without the fungus. The plate was masked with a leaf design, leaving the centre part exposed.

In some of the luminous bacteria the blue and violet rays of the spectrum predominate, and they have consequently been photographed by their own light. B. Fischer has also demonstrated that the light from streak cultures of these microbes is sufficiently strong to illuminate and photograph adjacent objects, such as a watch.*

Supposed cause of the phenomenon.

As a consequence of respiration or the combustion of carbon compounds, heat is liberated in all living plants, but the development of light only rarely takes place. As we have seen, only a few fungi become luminous, and it is found that as the respiration becomes feebler the light decreases in intensity and ceases entirely at death.

The production of light is also usually confined to certain portions of the organism, and may occur either in the vegetative portions or the fructification. In *Armillaria mellea*, for instance, it is only the mycelial strands and the fine white threads permeating the wood of the trees on which it grows that emit the light, so that the decaying wood among which they ramify is often spoken of as luminous. In *Pleurotus olearius*, on the other hand, the entire fructification is luminous, consisting of stalk, pileus and gills, while in others, such as the present one (*P. candescens*), the gills alone are luminous. Although the luminosity is confined exclusively in some cases to the vegetative organs and in others to the organs of reproduction, still the distinction is not absolute, for in the fungus under notice I found that the fresh downy material at the base was also luminous.

* Lafar. Technical Mycology, p. 164 (1898).

As far as has been determined, the conditions which influence the production of light are the following :—

1. It is only in the living organism that the phenomenon occurs, and the greater the vital activity the more marked is the phosphorescence. Brefeld* observed in the mycelial strands of *A. mellea* that only the youngest and softest portions were phosphorescent, while the older brown and hard strands were no longer capable of it.

2. Oxygen is necessary, for as soon as it is withdrawn the luminosity ceases, but it reappears when the air is restored. In pure oxygen the light does not become more intensive.

3. Phosphorescence is also dependent on the temperature. There is a minimum below which the light immediately ceases, and a maximum of luminosity beyond which temperature the light decreases until the heat is sufficient to kill the fungus, and then the luminosity is gone for ever. It appears that the minimum, the optimum and the maximum may vary in the same fungus according to its vital activity.

4. As regards moisture, the luminosity does not appear to be affected by wet or dry weather. I immersed a small portion of the gills of *P. candescens* in water for an hour and a half, and the light was practically the same at the end of that time.

Phosphorescence has been proved to be due to minute organisms—the photogenic bacteria—in the case of sea fish and animal flesh, but although bacteria are present on the gills of this fungus they have nothing to do with the phosphorescence. It will be noted that the luminous bacteria occur on flesh and the carcases of fish and are living organisms, just as the fungi are only phosphorescent while alive. It was concluded by Fabre† that phosphorescence is the result of the respiratory activity of the fungus, but that would hardly account for the phenomenon being restricted to certain parts nor for its being confined to so few forms of fungi. Even if due to a temporary increase of oxidation the exciting cause of such increase would require explanation.

* Schimmelpilze iii., p. 171.

† Ann. Sci. Nat. Series iv. Vol. 4 (1853).

It is a debated question whether the light proceeds from within the organism or from excreted luminous metabolic products. The researches of Radziscewski* seem to afford a reasonable and simple explanation of the luminosity, and they support the latter view. He found that certain organic substances such as the aldehydes and aldehyde-ammonia derivatives, as well as fatty oils, have the faculty of becoming luminous in alkaline solutions when oxygen is present. Such compounds (*e g.*, fatty oils) are known in the phosphorescent fungi, and if they are united in an alkaline solution with the oxygen obtained in respiration, the cause of the luminosity might thus be explained. Oxidation products or acids are formed from the luminous materials by the vital activity of the organism and the luminous organs in *P. candescens*, viz., the gills, were decidedly acid. The metabolic products are known as *phosphorescents*, and, uniting with oxygen, they evolve light outside the organism.

Luminosity is a better term for the phenomenon than phosphorescence, since it is not of the same nature as true phosphorescence. The luminous fungi glow without previous exposure to the sun, and the property cannot be excited by mere heat, as in the case of certain mineral substances such as phosphorite. Further, it is not due to the formation of some readily oxidizable compound of phosphorus such as phosphuretted hydrogen in the organism, as has been shown by Pflüger. It is essentially a vital phenomenon, disappearing immediately on death, and probably the energy set free in the process of destructive metabolism is evolved in the form of light.

Use of phosphorescence to the plant.

As regards the use of this luminosity to the plant, it may be surmised that it serves to attract various insects to aid in the dissemination of the spores. Just as many night-flowering plants are white to reflect the smallest possible amount of light in order

* Bericht Ludwig's in Bot. Centralbl. Vol. vii., p. 325.

to guide the nocturnal moths, so the luminous light of these fungi will guide the flies and beetles in the dark direct to the spore-bearing portion. In addition to the light, there is a strong odour, at least in this particular species, and so the night-flying insects will be attracted just as the day-loving insects are guided by the bright colours and the penetrating odours of other members of this large family.

Technical Description.

PLEUROTUS CANDESCENS, F.v.M.—**Glowing Pleurote.**

Caespitose, imbricated, with strong smell, phosphorescent. Pileus up to 6 inches across, fleshy, soft, sub-dimidiate, at first convex and horizontal, then becoming puckered, conchate, generally concave beneath or sometimes above, glabrous, moist, even, satiny, yellowish to brownish or becoming lavender; flesh white, cuticle may become separable. Stem short, stout and thickened upwards, from 2-3 inches long, firm, obliquely ascending, lateral or excentric, white to yellowish, downy at base.

Gills decurrent, moderately crowded, broad, white, with a yellowish tinge.

Spores white, elliptical, $7\frac{1}{2}$-$9\frac{1}{2} \times 4\frac{1}{2}$-$5\frac{1}{2}$ μ.

Beaumaris, Victoria; on trunks of Tea-tree or on the ground arising from the roots; April-May, 1900.

There is a considerable amount of variation in this species. The colour may vary from yellowish to brownish or even be entirely lavender in specimens of the same size. In the self-same tuft, the stems may be lateral or excentric, or practically central, while the pilei may be conchate or round and slightly convex. This variation is largely caused by the extensive overlapping and the necessity of each one accommodating itself to its surroundings. From 9 to 12 may spring from a common base, and spreading out horizontally and overlapping each other, they must vary in shape, especially when some of them have a diameter of 6 inches. They are found on the trunks of living trees, although usually the particular spot from which they spring is dead, but this is probably caused by the mycelium destroying the tissues.

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Gives an enumeration of known phosphorescent fungi at that date.

EXPLANATION OF PLATE.

Fig. 1.—Group showing habit of growth.
Fig. 2.—An individual, showing gills (nat. size).
Fig. 3.—Group of spores ($\times 1000$).